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ABSTRACT

Infants' visual perception of number change was investigated in three studies. These studies focused on infants' perception of events in which the total number of objects in a small group was changed through addition of another object. Involving 60 infants 5 months of age, Study I attempted to determine whether subjects perceived the properties in additions of one object to sets of one or two moving objects as: (1) change versus non-change, (2) the size of the set that was changed, or (3) the number of objects added to a set. A similar study was conducted with 12 infants 15 months of age. Study II, involving 12 infants who were 8 months old and 20 infants 13 months old, investigated whether infants perceived events that involved addition of an object and whether they could discriminate such an addition from a non-change and a larger change. In Study III, 12 infants 13 months of age were involved in an attempt to determine whether they perceived that the addition of one object to a certain set of objects specifies one outcome only. Generally, findings indicated that infants up to 13 months of age seem to be able to perceive components of events that involve number change. Such components were the number that is changed and the size of the change. However, they did not seem to perceive the relationship of such components under a number transformation. (RH)

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PERCEPTION OF NUMBER CHANGE IN INFANCY

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Our research addresses the development of early number perception. It may be argued that the development of number perception presupposes detection of number constancy and detection of changes that effect number. Children should know which transformations involve a change of number and which do not. For example, changing spatial relationships among a collection of objects through movement does not change their number, whereas addition or deletion of objects does. Recent findings suggest that certain numerical skills are available in infancy (e.g., Cooper, 1984; Starkey & Cooper, 1980; Strauss & Curtis, 1981, 1984). It is, however, not clear from these studies whether infants perceive number constancy and number change.

Number can be conceived as an invariant property of a collection of objects. Under certain conditions there is visual information available to the perceiver that specifies number constancy. Such information is available when objects move and their spatial positions change continuously over time (Smitsman, 1985). We have already demonstrated that infants of 5-months of age can perceive number constancy (van Loosbroek & Smitsman, 1986). But we do not yet know whether infants are able to recognize number changes such as when objects are deleted or added. Therefore, infants' visual perception of number change was investigated in a series of studies. Specifically, we focussed on infants' perception of events in which a small number of objects was changed through addition of a novel object.

Study I

Number change involves several components. An example of the structure of an addition of an object is: 2 dogs play together on a field; after a while a new dog enters the field and starts to play with the other 2 dogs; there are now 3 dogs. Several components may be discriminated in this event: the entering of a new dog, the number of dogs before the addition and afterwards, and the number of dogs that were added. It is possible that for infants recognition of the components is dependent on the number of objects involved. Therefore, set size was varied. It was investigated whether 5-month-old infants perceive properties in additions of 1 object to sets of 1 or 2 moving objects as: a) change versus non-change; b) the size of the set that is changed; c) number of objects added to a set. The infants were habituated to visual displays of events involving addition of one object.

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Method

A total of 60 infants of 5-months of age participated in this study. The procedure used was an infant-controlled habituation of visual looking time task (Horowitz, 1974). Each infant was habituated to events that consisted of the addition of 1 object to 1 or 2 objects in two separate, randomly ordered sessions, respectively. An addition was displayed on a black-and-white T.V.-monitor in the following way: First a certain number (1 or 2) of moving objects was shown. After approximately 2 seconds a new object came into view by a disocclusion from one of the sides of the T.V.-monitor and mixed with the other object(s). The addition-part of the event took approximately 5 seconds. The whole event thus took approximately 7 seconds. After each presentation an empty screen was visible for approximately 1 second. Then the whole event was repeated with the same figures, movements and grey-colors. Figures were randomly filled squares. The movements progressed at a constant rate along curvilinear trajectories at varying orientations. In these movements, figures could partly and temporarily occlude other figures. The movements, number of occlusions, figures and grey-colors were varied for every trial.

The beginning of each trial was signalled by a tone. A trial consisted of a repeated presentation of an event until either one of the two following conditions were met: the event had been presented at least once, the infant had looked at least for 1 second and, following that, had continuously looked away for 2 seconds or the infant had a total of 10 fixations. The first three trials of the habituation phase were used to compute the habituation criterion. The criterion was half of the mean fixation time on these first three trials. The habituation phase was ended and the test phase was started when either one of the two following criteria was first satisfied: either the habituation criterion was reached on three consecutive trials or after a randomly determined number of trials that could range from 16 to 23. The test phase in this study consisted of four trials (two Old-trials and two Novel-trials). On O-trials the event of the habituation phase was again presented. On N-trials a novel number event was presented. Depending on which of the three conditions the child was assigned to, the events could consist of: 1) the sum of the addition in the habituation phase (x+1), in other words, no change of number was involved; 2) an addition with the same addend (+1) as in the habituation phase but to a novel augend (x= 0 or 1); 3) an addition with a larger addend (+2) than in the habituation phase but to the same augend (x= 1 or 2). Test-trials were presented in two different orders: O-O-N-N or N-N-O-O.

Results

In the analyses, fixation times for both N-trials were always compared with the fixation times on the preceding O-trials. That is, for the O-O-N-N-order the O-trials were the two preceding trials in the test-phase. For the N-N-O-O-order, however, the O-trials were the last two trials in the habituation phase rather than the two subsequent O-trials in the test-phase. In the latter case, the fixation times were corrected for the spontaneous regression in fixation time that was found between the last two trials in the habituation phase and the two old number trials in the test-phase immediately following the habituation phase. (See Bertenthal, Haith & Campos, 1983, for a discussion of this design.)

Visual fixation times of children were transformed by dividing the total fixation time on each trial by the combined fixation times on the three trials preceding the test-phase. An analysis of variance was performed on the transformed fixation times with the following factors: type of new number event (sum; smaller augend; larger addend), trial-type (habituation vs. test trial), number (1, 2) with repeated measures on the last two factors. The results revealed no differences across or within conditions (see table 1). Infants did not look longer in the test trials than in the habituation trials for any number presented for whatever event. It was also investigated whether the additions presented differed for the infants in preference. An analysis of variance on the combined fixation times for the first three trials revealed that infants looked longer at the event of 2+1 than at the event of 1+1, suggesting that 2+1 might be more interesting or more difficult.

Table 1. Combined Untransformed Fixation Time Scores in Seconds for Type of Novel Event (sum, smaller augend, larger addend), Number (1, 2) and Trial Type (habituation vs. test trials).

Event	Sum		Smaller Augend		Larger Addend	
Number	1	2	1	2	1	2
Trial						
Habit.	27.56	18.42	20.68	22.98	19.70	18.00
Test	28.79	15.96	18.83	24.52	20.16	15.96

A similar study was conducted with 12 infants of 15-months of age. However, movements were linear here, they were slower so that the whole event took more time (11 seconds), and only the addition of 1 object to 2 objects was investigated. The three novel number events (sum; smaller augend; larger addend) were within subject conditions.

Results

Comparisons of transformed fixation times on habituation and test trials revealed longer looking times on test trials when the events involved no number change or a larger number change than in the habituation phase. However, no longer looking times on test trials were found when events involved the same number change as in the habituation phase but for a smaller set of objects.

Table 2. Combined Untransformed Fixation Time Scores in Seconds for Type of Novel Event (sum, smaller augend, larger addend), and Trial Type (habituation vs. test trials).

Event	Sum	Smaller Augend	Larger Addend
Trial			
Habit.	15.84	21.03	15.63
Test	30.97	22.76	35.44

Study II

Although we found some support for the ability of older infants to perceive components of events involving addition, it is unclear whether they are able to perceive a relationship over time between numbers that are changed. Specifically, we can ask whether infants perceive events that involve addition of an object and whether they can discriminate such an addition from a non-change and a larger change.

Method

A group of 8-month-old infants (n=12) and a group of 13-month-old infants (n=20) were studied. Each infant was habituated to an addition of one object to two different numbers of objects (1 and 3). So, in alternating trials, infants were presented with the additions 1+1 and 3+1. Such an addition was displayed in a procedure that was adapted from von Hofsten and Lindhagen (1982). An example of the addition (1+1) is the following: one object moves from the right side of the monitor along a curvilinear trajectory to the left. Halfway it disappears behind a small bar and reappears on the other side of the bar. However, a novel object also reappears so that the number of objects is now one more than was the case when these objects were moving on the right side of the bar. The whole event took approximately 11 seconds. Movements, number of occlusions, figures and grey colors were varied for every trial. The habituation procedure was similar to that employed in the last study except for the ending of a trial. Here, a trial was ended after an event had been shown at least twice, had been completed and after an infant had looked at least for 1 second and looked away for 2 seconds continuously or after the infant had a total of 10 fixations. After the habituation criterion was reached, or after 23 trials, a test phase was started consisting of four trials: two trials consisting of the Old change (+1) but for a novel number (2) and two trials showing a Novel change (either +0 or +2, depending on the condition to which the infant was assigned) also for the number (2). Test trials were presented in two different orders: O-O-N-N or N-N-O-O. Infants were assigned to the two change conditions (2+0 or 2+2) in two randomly ordered sessions.

Results

Looking times were analysed for each condition at each age. On no occasions were differences found between the two trial types within the test phase (old change: 2+1 vs. novel change: 2+0 or 2+2), indicating that infants did not perceive the relationship of change between two numbers within the structure of the event presented. However, comparisons between the last two habituation trials and the combined test trials (old and novel change) revealed significant differences in looking time at both ages but only when test trials involved a novel change of 2 objects (p's < 0.01) and not when they involved number constancy (p's $> .15$; see also table 3).

Table 3. Combined Untransformed Fixation Time Scores for Age (8, 13 months),Type of Novel Change (2+0 or 2+2), and Trial Type (habituation, old test, novel test trial).

Condition	Number constancy (2+0)		Larger number change (2+2)	
Age	8	13	8	13
Trial				
Habit.(1+1/3+1)	22.5	24.2	16.3	25.5
Old Change (2+1)	27.8	29.9	28.3	41.6
Nov.Ch(2+2 or 2+0)	31.2	32.8	28.4	44.4

These results seem to indicate that infants that are 8-months of age and older may be capable of perceiving at least the number of objects that is changed. Perhaps the type of change (e.g., numerical vs. non-numerical) may also have been detected, for infants do not always dishabituate. The absence of dishabituation for the condition involving number constancy may be explained as a consequence of the too large disparity between habituation and test phase. Disparity between habituation trials, always involving addition of 1 object, and test trials appears to be larger for the condition in which some test trials involve a larger number change. It is known that dishabituation may not occur if disparity between habituation and test trials is too large (Kagan, Linn, Mount & Reznick, 1979).

Study III

It is still unknown whether infants perceive that the addition of 1 object to a certain set of objects specifies one outcome only, that is, a unique number and not a smaller or larger number. This question was addressed in the present study.

Method

A group of 13-month-old infants was (n=12) studies in two randomly ordered sessions. In each session they were habituated to two correct additions (1+1=2 and 3+1=4) that were alternately presented. An addition of an object was shown the manipulation of real objects. For example, if the addition 3+1=4 was shown, infants were first prsented with three identical small red cubes. Then the objects were concealed by a container that was placed over them. Subsequently, another red tube was added when an experimenter gradually brought a novel tube above the container, turning it clearly and then putting it in the container. Finally the container was taken away and the number of tubes that formed the content was revealed (e.g. 4 tubes). In the test phase additions of 1 object were also presented but for a novel augend. Furthermore, the sum revealed could be either correct (2+1=3), as the additions in the habituation phase, or incorrect (2+1=2 or 2+1=4, depending on the condition to which the infant was assigned).

In order to ensure a constant duration of the addition event, the experimenter performing the addition was guided by a visual display that

indicated how long the various components of the addition event should take. The total event took 22 seconds. The habituation procedure was adapted in some ways. The habituation criterion was computed on the frist two trials and this criterion could be reached on two consecutive trials or after 13 trials. The order of presentations in the test phase was either C-I-C-I or I-C-I-C (C: correct sum; I: incorrect sum).

Results

Looking times were analysed for each condition. On no occasions were differences found between the two trial-types within the test phase or any dishabituation on test trials compared to the last two habituation trials. These results indicate that infants did not abstract addition of an object to a number of objects. In other words, they did not expect a particular outcome for the transformation x+1.

General Conclusion

Infants up to 13-months of age seem to be able to perceive components of events that involve number change. Such components are the number that is changed and the size of the change. However, they do not seem to perceive the relationship of these components under a number transformation.

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